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CERAMIC PLUTONIUM TARGET DEVELOPMENT FOR THE MASHA SEPARATOR FOR THE SYNTHESIS OF ELEMENT 114

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1. Introduction

We are currently developing a Pu ceramic target for the MASHA mass separator. MASHA will use a Pu ceramic target capable of tolerating temperatures up to 2000 ºC. Reaction products will diffuse out of the target into an ion source, and transported through the separator to a position-sensitive focal-plane detector array for mass identification. Experiments on MASHA will allow us to make measurements that will cement our identification of element 114 and provide data for future experiments on chemical properties of the heaviest elements. In this study $(Sm,Zr)O_{2-x}$ ceramics are produced and evaluated for studies on the production of Pb (homolog of element 114) by the reaction of Ca on Sm. This work will provide an initial analysis on the feasibility of using a ZrO_2-PuO_2 as a target for the production of element 114.

1.1. *The MASHA Separator*

The MASHA (Mass Analyzer of Super Heavy Atoms) on-line mass separator is currently under development at the Flerov Laboratory of Nuclear Reactions at JINR. This separator is expected to have a number of improvements over existing recoil separators, and will provide at least a ten-fold increase in the production and detection rate for element 114. It will allow unambiguous mass identification of super heavy nuclei with a mass resolution below 1 amu [1]. An improvement in MASHA is the use of a thick, Pu ceramic target heated to a temperature of approximately 2000°C. The ceramic will see a large range of beam energies and a larger percentage of the excitation function will be sampled.

The target will be a combination actinide target and the ion source of the CERN-ISOLDE type [2,3]. Reaction products will diffuse out of the heated, porous target and drift to an ion source to be ionized and injected into the separator. After traveling through the separator, the products will impinge on a position-sensitive focal-plane detector array for mass measurement. Initial tests will use surrogate products, but ultimately, element

114 experiments will be performed using ceramics containing ^{244}Pu to be irradiated by ^{48}Ca ions [4].

The Pu target for MASHA must meet several requirements; physically stable and able to withstand 2000 °C without melting or large thermal expansion. The target phases must be thermodynamically stable over the temperature range without undergoing phase transitions. The Pu vapor pressure should be low and the diffusion rate of reaction products from the target must be fast enough to allow measurement of short-lived products.

2. Candidate Plutonium Compounds

There has been previous work on the fabrication and characterization of actinide containing ceramics including solid solutions of different actinides [5,6]. Various zirconia containing ceramics with actinides have been fabricated and studied, including ZrO_2-PuO_2, [7-9]. The properties of ZrO_2-PuO_2 have been examined by experiment and by model, concluding that $(Pu,Zr)O_2$ based targets should have suitable properties for the production of element 114. Solids solutions of ZrO_2-PuO_2 composed the best ceramic properties, ease of synthesis, and single phase over a large range. For these reasons ZrO_2-PuO_2 will be chosen as the final target matrix.

3. Methods and Results

3.1. *Sm Surrogate Targets*

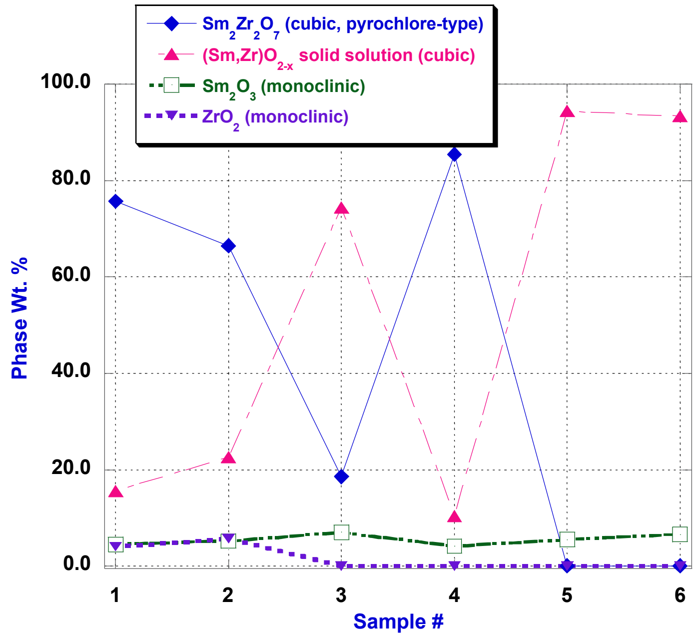
In order to begin tests of the MASHA target – ion source combination, we have synthesized surrogate targets consisting of mixtures of ZrO_2-Sm_2O_3 in several different ratios (Table 1). The rare earth element Sm has an electronic configuration ([Xe] $4f^5$ $6s^2$) that is analogous to that of the actinide Pu ([Rn] $5f^6$ $7s^2$) such that the two may behave similarly in a ceramic matrix. More importantly, Sm is a target homolog of Pu, the reaction between Sm and the ^{48}Ca beam results in short-lived lead isotopes, which are homologues of element 114.

Table 1 Composition of samples. The Sm and Zr values are in mol % and the stearate and PEG in wt %

Sample #	$SmO_{1.5}$	ZrO_2	Zn Stearate	PEG
1	65	35	3	3
2	65	35	3	6
3	80	20	3	3
4	80	20	3	6
5	50	50	3	3
6	50	50	3	6

By bombarding these targets at elevated temperatures, the diffusion of lead reaction products out of the target can be measured as a function of Sm concentration and ceramic porosity. The results from these initial experiments will aid us in the preparation of subsequent Pu ceramics. The samples were prepared with stearate as a binder and polyethylene glycol added to increase void volume and sintered at 1600 ºC. The samples were analyzed by X-ray powder diffraction (PANalytical Expert Pro) using Cu $K\alpha_1$-$K\alpha_2$ emission with the addition of NIST SRM 640a, silicon as a standard. The pattern were taken between 10° and 120° 2 theta with step sizes of 0.008° 2 theta and 25 seconds count time per step. The phase analysis was performed by applying Rietveld structure refinement (Bruker AXS Topas2) (Figure 2).

Figure 1. Phases in the different Sm-Zr oxide sample



4. Conclusions

Candidates for the MASHA target are currently being prepared and characterized. On-line tests with MASHA will begin with surrogate Sm targets, but subsequent irradiations with ^{242}Pu and ultimately ^{244}Pu will be performed. Once the target is prepared and tested, experiments designed to measure the mass of element 114 will begin.

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